Secondary Electron Yield Measurements on Materials of Interest to Vacuum Electron Communication Devices

Talal Malik
Department of Electrical and Computer Engineering
University of New Mexico
Albuquerque, NM 87131, USA
tmalik@unm.edu

Mark Gilmore
Department of Electrical and Computer Engineering
University of New Mexico
Albuquerque, NM 87131, USA
mgilmore@unm.edu

Salvador Portillo
Department of Electrical and Computer Engineering
University of New Mexico
Albuquerque, NM 87131, USA
sportil@unm.edu

Edl Schamiloglu
Department of Electrical and Computer Engineering
University of New Mexico
Albuquerque, NM 87131, USA
edls@unm.edu

Abstract: *Vacuum electron devices (VEDs) can experience degraded performance, including complete failure, due to multipactor breakdown (MPB). This effect is tied to the production and acceleration of secondary electrons due to electron impact and coupling to the RF fields. In order to better understand the initiation of MPB with materials of interest, researchers at the University of New Mexico (UNM) are carrying out a study of the secondary electron yield (SEY) contribution from various materials used in high power VEDs. This work describes SEY data from electron bombardment in the low energy regime, from 10 eV to 1 keV, on Cu as a baseline material, - stainless steel, aluminum 6061 (Al) and Invar (Fe64/Ni36). SEY data for Cu as a function of incident beam angle is also presented. In addition, different surface cleaning treatment protocols employed in this study will be described.*

Keywords: Multipaction; SEY; ultrasonic cleaning; IR heating; XPS

Introduction

The multipactor effect is the process of electron multiplication in vacuum under the influence of RF fields. SEY is important in initiating multipactor breakdown. Multipaction is a significant engineering problem in high power VEDs and has the ability to degrade their performance. In this study of SEY, we will present the experimental set-up that has been established to measure data from materials described in the abstract. Figure 1 presents the schematic of the experimental set-up. The goal of this experimental study is to research surface cleaning protocols and measurement techniques in order to establish consistent SEY data. The overall goal of this project is to characterize the SEY of new materials developed using first principles density functional theory (DFT) to have lower SEY.

We will be exploring a couple of surface cleaning protocols and their effect on SEY measurements. The following protocols were used:

1. samples are roughened using sandpaper and wiped with methanol, and
2. a three step ultrasonic cleaning is invoked.

The latter protocol is the three-step industrial prescribed surface cleaning methodology. It involves a five-minute ultrasonic treatment with acetone, followed by detergent and then rinsed with deionized water.

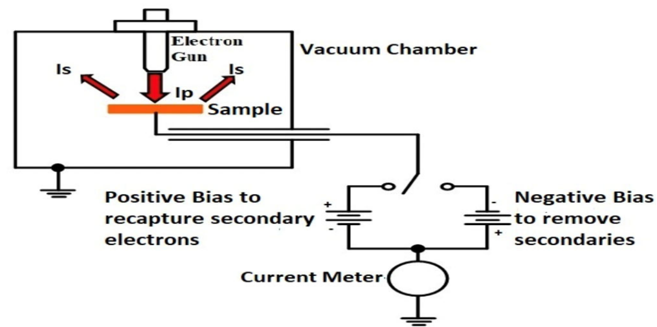

Fig. 1. Schematic of the SEY experimental set-up.

Experimental Set-Up and SEY Results

The first goal in the experiment is to establish ultra-high vacuum condition inside the chamber. To achieve a base pressure of 10^{-8} Torr, a combination of roughing and turbo pump was used.

The SEY coefficient δ is measured as $\delta = I_s/I_p$ [1] $= I_p - I_t/I_p = 1 - It/I_p$. I_p is the primary beam current, which is measured by biasing the sample at +100V and I_t is the target current which is calculated by applying -20 V to the sample. It should be noted that, $I_t = I_p - I_s$ where I_s is the secondary electron current. The Cu sample was first tested as the baseline. Its SEY was measured by using protocols 1 and 2 of surface cleaning. In Fig. 2, the SEY data measured for each cleaning protocol compared to check the effectiveness of the cleaning methods in terms of lower SEY. The ultrasonic treatment of Cu yields lower SEY as compared to protocol 1.

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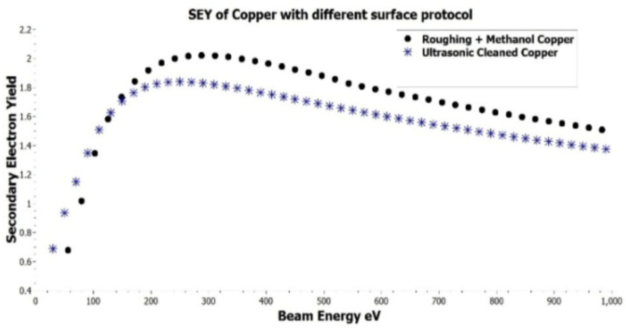

Fig. 2. Comparative analysis of the SEY of Cu with two different cleaning protocols.

Figure 3 shows the effect of ultrasonic cleaning on the Cu sample with the incident electron beam at different angles of incidence. It is observed that the SEY increases with increasing angle of incidence. The peak value of SEY is minimum at 0° and maximum at 30°. This trend of increase in SEY with increasing angle of incidence, although different cleaning protocol employed, is in good agreement with published data [2].

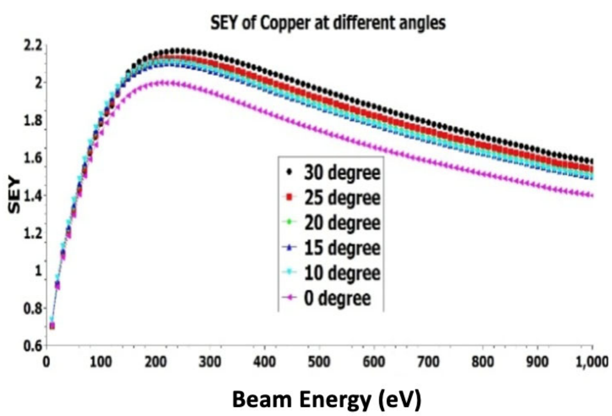

Fig. 3. SEY of ultrasonically cleaned Cu at different angles of incidence for the electron beam.

Figure 4 presents a comparative analysis of the SEY for four metals which were subjected to cleaning protocol 2. It is evident from the results that Cu has the lowest SEY while Al has the highest SEY. Cu is usually considered to be the material with lowest SEY while Al is the higher SEY material.

Thus far we have found that ultrasonic treatment has produced good results for Cu. Figure 5 shows a comparative analysis of the SEY protocol 1 for the same four metal samples shown in Fig. 4. The SEY results for protocol 1 show that SEY for Cu is still lowest while SEY is highest for the sample of Invar. The change in SEY results for cleaning protocol 1 is due to the reason that SEY is surface specific phenomenon and different processes on the surface of materials yield different SEY.

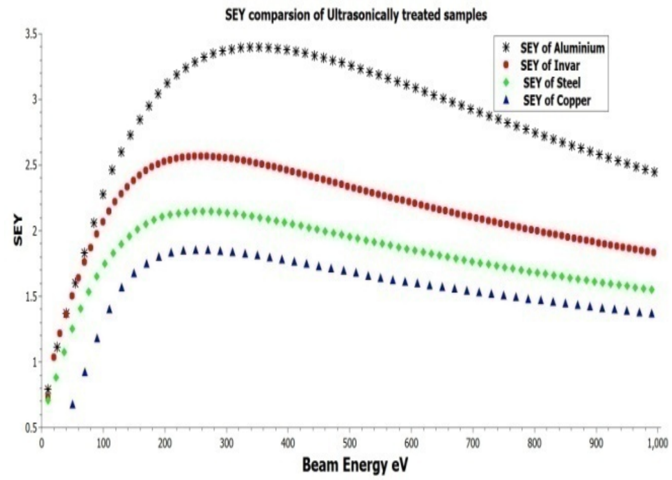

Fig. 4. Relative SEY analysis for cleaning Protocol 2.

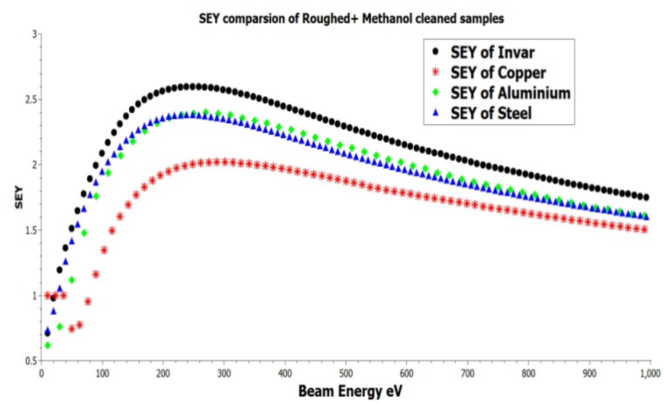

Fig. 5. Comparative analysis of the SEY for cleaning protocol 1.

Baking the samples has a significant effect on the SEY measurements. We are currently working on heating the samples up to 300 Celsius through an IR heater and then measuring the SEY. The aim of heating is to clean the surface as much as possible and to get rid of contaminants and adsorbed water molecules on the surface of the sample. The process of heating is expected to yield a lower value of SEY. Once we are done with heating, we will propose a final cleaning protocol that will yield lower SEY. We also plan to measure SEY on various materials from collaborating universities. Our future work also includes using in-situ X-ray photoelectron spectroscopy (XPS) surface analysis to determine the composition of the layers on the sample surface before and after the experiment.

References

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